HFR Surface Currents Observing System in Lower Chesapeake Bay and Virginia Coast

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Abstract-**Surface currents are measured using high frequency (25MHz and 5MHz) radar in the lower Chesapeake Bay and offshore in the Mid-Atlantic. The data have become quite reliable and of high quality over the past couple of years. This paper describes the existing system, the dataset, the quality of data and some examples of how it is being used. It also presents results of recent analysis of mean currents within the lower Bay.**

I. Introduction

Surface currents are measured using high frequency (25MHz & 5MHz) radar in the lower Chesapeake Bay and offshore in the Mid-Atlantic. The data have become quite reliable and of high quality over the past couple of years. This paper describes the existing system, the dataset, the quality of data and some examples of how it is being used. It also presents results of recent analysis of mean currents within the lower Bay.

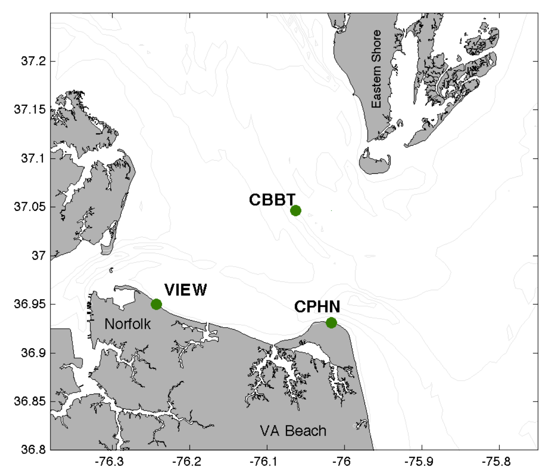

Figure 1. Location of CODAR units in lower Bay and navigation buoys.

Three CODAR 25 MHz SeaSonde units are located in the lower Chesapeake Bay: one at the City of Norfolk Community Beach in Ocean View (VIEW), another atop the Fourth Island of the Chesapeake Bay Bridge Tunnel (CBBT) and a third housed at the Fort Story Army Base at Cape Henry (CPHN). The CPHN unit is owned and operated by the NOAA CO-OPS office. Additionally, Old Dominion University operates three 5 MHz SeaSonde units located along the coast at Little Island Park (LISL), Cedar Island (CEDR), and Assateague Island (ASSA). These units look offshore and are part of the larger Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS), which is itself a part of the National Integrated Ocean Observing System (IOOS). These units are operated in collaboration with the Center for Innovative Technology in Herndon, Virginia. This paper focuses on the units in the Bay.

The CBBT site was installed in late February 2007 and the VIEW site was installed in April 2007. At least two sites are needed to compute total current vectors and so the data set

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essentially begins in April 2007. The CPHN site was added in late February 2008. It did not collect data from late March to mid-June due to renovations at the Army facility, but it has been in operation since June 2008.

II. Data Access

A. National Access

The Chesapeake Bay and offshore coastal data is imported directly into the National HFRADAR network system and may be viewed through the National Network website hosted at Scripps (http://cordc.ucsd.edu/projects/mapping/maps). A typical visual is shown in Figure 2.

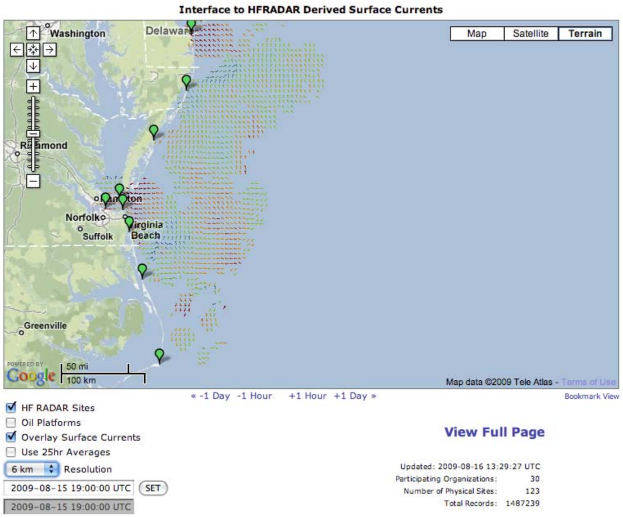


Figure 2. Sample visual from the national node at Scripps.

B. Regional Access

Since the data are of local and regional interest in different forms, ODU also provides a website (http://www.ccpo.odu.edu/currentmapping) displaying a variety of visualizations (Fig. 3) of the data from the lower Bay.

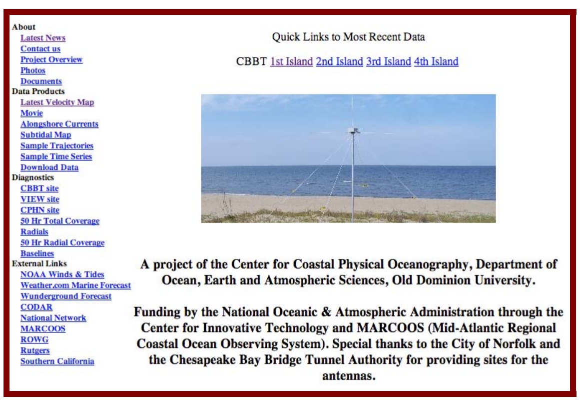


Figure 3. Sample webpage from the ODU website for the lower Bay.

III. Typical Products

There are many products provided to users. Following are examples of a few representative ones. Figure 4 shows a typical surface current map representing the last hours averaged data.

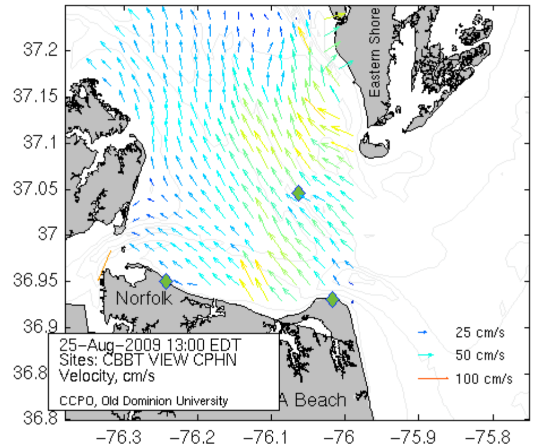


Figure 4. Typical surface current map produced hourly for the lower Bay.

Figure 5 shows the currents in the shipping channels. This is a product under development and the ultimate goal is to provide a short term forecast for the shipping channels for mariners.

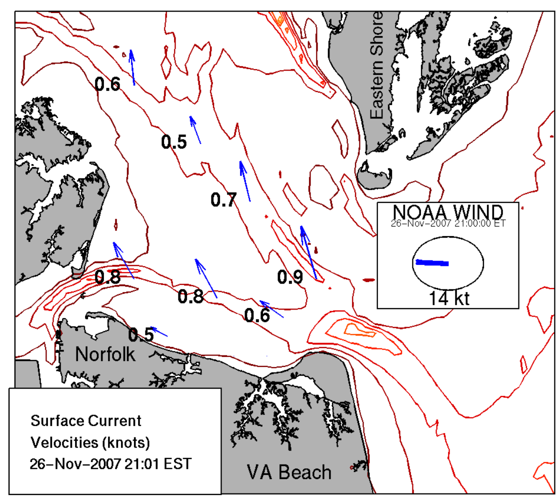


Figure 5. Currents in the shipping channels.

Alongshore currents are often important for rescue and pollutant tracking. Figure 6 shows alongshore currents off of the Ocean View Bay Beaches. The black line represents a spatial average of the currents along the shore and positive values indicate westward flow.

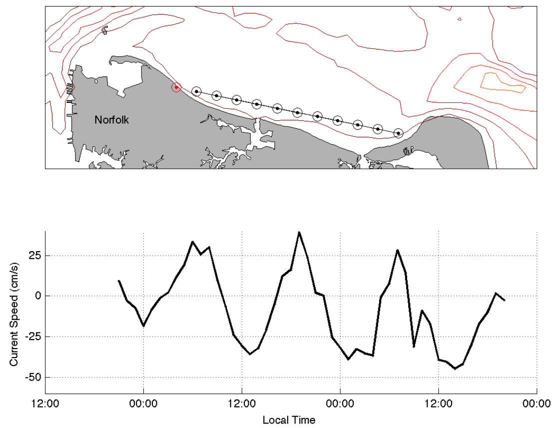


Figure 6. Alongshore currents off the beaches of Norfolk and Virginia Beach.

Sample trajectories of floating particles, which can also be used for search and rescue or pollutant tracking, are shown in Figure 7.

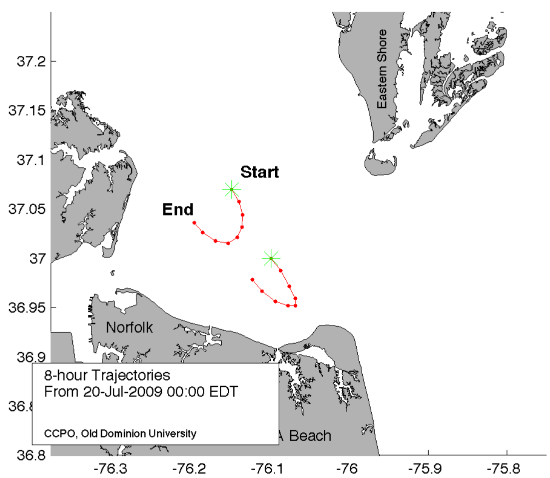


Figure 7. Example of eight hour trajectories of surface particles.

Surface currents are an important search and rescue tool for marine patrol groups. The offshore data from the 5 MHz systems are automatically ingested in to the Coast Guard search and rescue database (SAROPS). The 25 MHz data is not yet available in SAROPS although the effort to include the inland Bay data in the MARCOOS region is underway. In the meantime, the Coast Guard in the Hampton Roads area receives one or more distress calls on most days of the year. Several of these incidents occur in popular fishing spots near the Chesapeake Bay Bridge Tunnel Islands. When a call is received, the local Coast Guard personnel would like to know the current velocity right then at the location of the incident along with a short time history of the velocity. Figure 8 shows a product under development for the Coast Guard focusing on the First Island of Bridge Tunnel. In the future, the graphic will include an estimate of the velocity at the point labeled NOW.

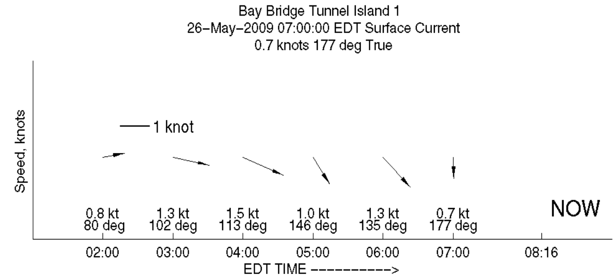


Figure 8. Current speed and direction at location of interest to search and rescue.

IV. Comparisons

A. Total Current Vectors

A comparison between surface current velocity vectors computed using the HFRADAR data and current observations from three NOAA Doppler current profilers on Aids- to-Navigation (ATON) buoys is made in near real-time every hour and displayed on the web (buoy locations marked in blue in Figure 9). The shallowest bin data available in real-time from NOAA are at depth bins centered at 6.7, 7.0 and 6.7 meters below the surface for York Spit (YS), Cape Henry (CH), and Thimble Shoals (TS) stations respectively. Temporal and horizontal spatial discrepancies exist as well (Figure 10 a, b, c). Generally the best comparisons are found at York Spit. The worst comparisons are at Thimble Shoals. In these cases, the ADCP is measuring current at depth in the middle of the shipping channel and the CODAR is observing current in the upper meter over a wider spatial area around the channel. For this particular time frame at Cape Henry, there are times when the CODAR data do not follow the tidal curve and are quite different from the ADCP values.

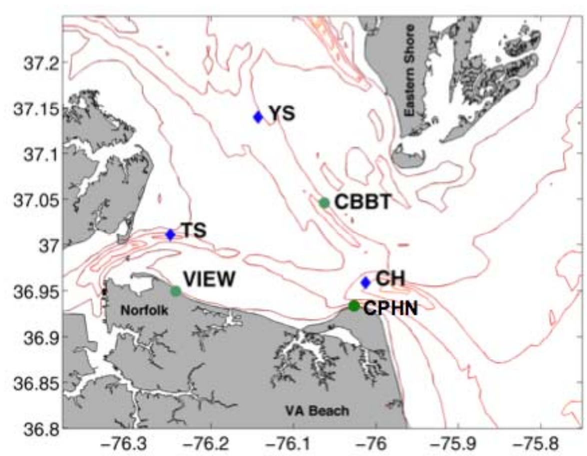
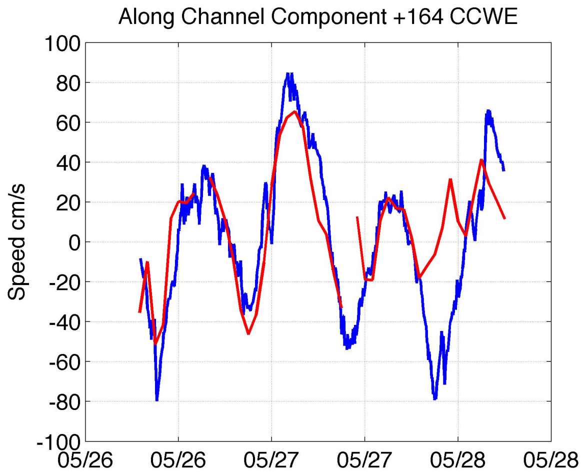
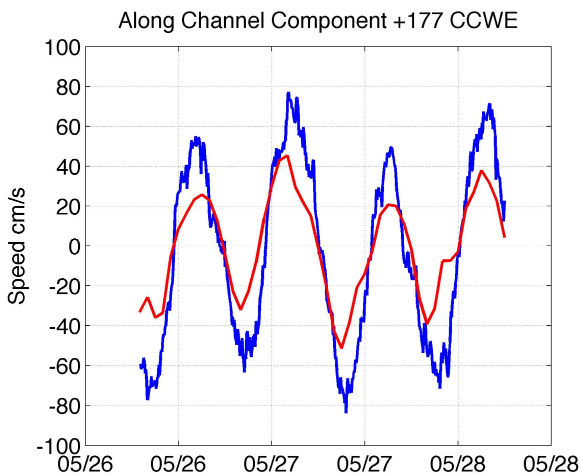


Figure 9. Location of buoys with ADCP current measurement devices: TS, YS, and CH





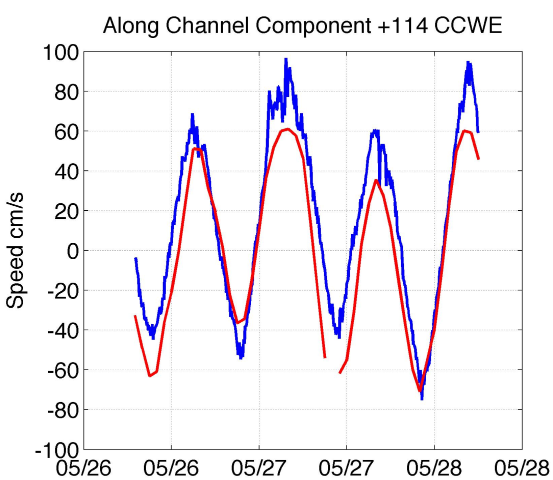


Figure 10. Current comparisons. Blue ADCP. Red CODAR. From top to bottom: YS, TS, CH.

B. HFR vs AWAC

A second comparison was made between the RADAR data and the observations from a Nortek Acoustic Wave And Current (AWAC) device located off of Ocean View beach to collect data for a beach erosion model. It is moored in approximately 7 meters of water 2 kilometers northeast of the VIEW antenna and it is roughly 0.5 kilometers from the nearest grid point where CODAR total vectors are routinely computed.

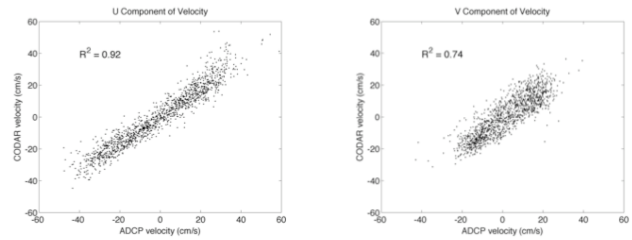


Figure 11. Scatterplots of ADCP data vs CODAR data for U and V components during AWAC deployment.

Deployment	**5**	**7**	**8**	**9**
Start Date	3/9/07	11/13/07	3/12/08	7/8/08
End Date	7/6/07	3/7/08	7/7/08	11/7/08
Npoints	1606	1345	659	2727
Mean (U)	-4.64	-1.04	-5.84	-5.01
Mean (V)	-0.29	1.21	-0.7	3.65
RMS (U)	10.57	6.19	13.09	11.74
RMS (V)	9.3	6.93	10.74	11.35

Table 1: Mean and root-mean-square statistics for the difference in velocity between the Doppler profiler and CODAR in U and V components for four deployment periods.

In these comparisons (Figure 11), the current data, spaced at twenty-minute intervals, were smoothed before velocity values were interpolated at the hourly time stamps of CODAR observations. CODAR velocities from the nearest grid point were subtracted from these interpolated ADCP data. The statistics for the difference time series are displayed in Table 1. The lowest root-mean-square values are found in deployment 7, particularly in the U component.

V. Sub-Tidal Current & Relation to Wind

A time series from April 2007 to July 2009 was analyzed in order to compute the mean sub-tidal current for the Lower Bay. Short gaps in space and time were filled by interpolation and the data were filtered with a Butterworth 36-hour low pass filter. The mean of the filtered data is shown in Figure 12. Only grid points that contained data more than 80% of the time were considered in the analysis. Note that the highest average sub-tidal currents are around 15 cm/s and are located in the middle of the Bay. A persistent feature in short and long term sub-tidal images is the recirculation present outside of the James River. A third feature that is shown in figure is the outflow concentrated toward the southern end of the Bay Mouth. This result is consistent with salinity and density fields from a fifteen-year Bay Mouth climatology in which the fresher, less dense water is located near the south end of the

Bay Mouth transect in all seasons (e.g. the winter season displayed in Figure 13).

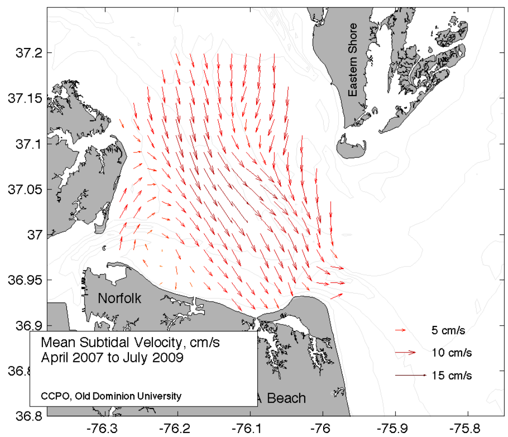


Figure 12. Long term (April 2007 to July 2009) surface currents.

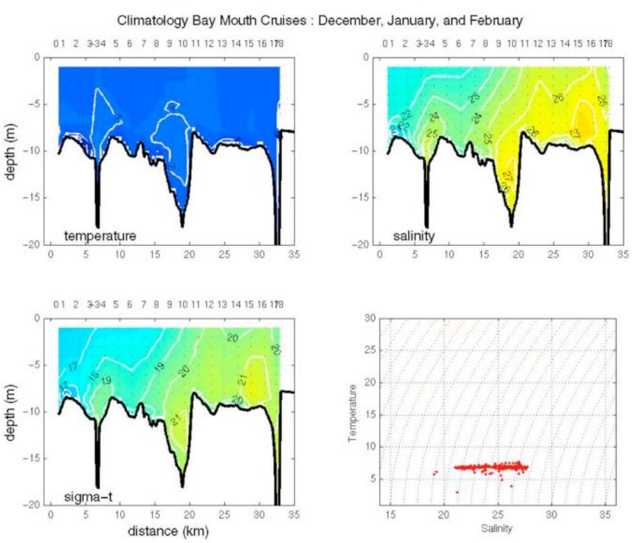


Figure 13. Mean climatology for the Bay mouth during the winter: Dec., Jan., and Feb.

The wind over the Lower Chesapeake Bay has dominant directions (Figure 14) that affect the sub-tidal flow in the area covered by HFR. The wind data displayed in the wind rose below was collected at the NOAA PORTS Bay Bridge Tunnel site and it represents filtered data over the same period as the current analysis described above. The wind rose follows the meteorological convention of “winds from a direction” and the speeds are given in meters per second.

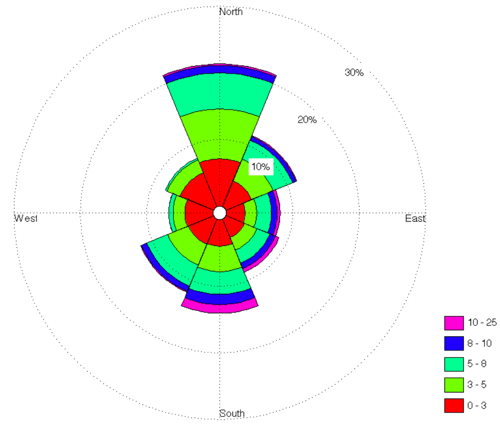
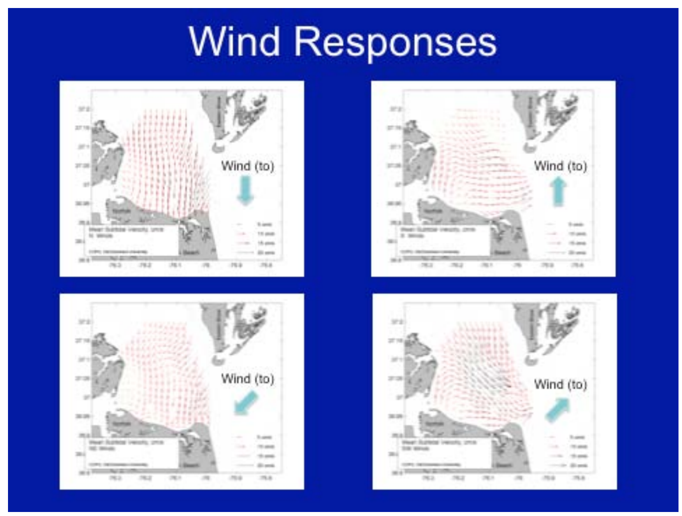


Figure 14. Winds in the lower Bay.

Figures 14 a-b show the sub-tidal surface currents under eight wind forcing directions. The two top maps show the dominant wind directions from the north and south.



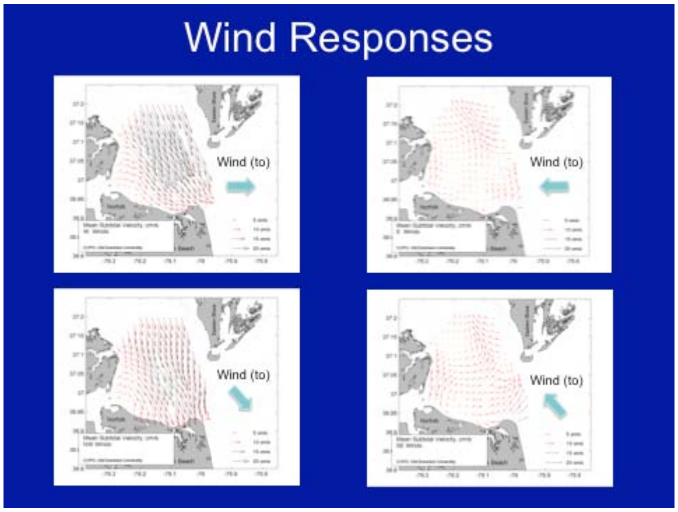


Figure 15. Average surface currents in response to different wind regimes. The large arrow shows the direction the wind is coming from.

The results seen so far suggest that it is possible to use this data set along with wind data and river discharge to answer basic questions about the local circulation including:

1) What is the combined effect of wind and river discharge of sub-tidal surface circulation?

2) What are the effects of severe storm events on circulation patterns?

3) What percentage of the total current velocity is due to the individual tide, wind and river discharge components?

VI. Data use

A. Search and Rescue

Data from the offshore looking units are being fed into the Coast Guard Search and Rescue. Additionally, data products are under development for specific use by local police groups.

B. Alongshore currents

Radial velocities from VIEW looking toward Cape Henry represent the alongshore current off of Ocean View Beach.

C. Oil spill response training

The Marine Spill Response Corporation (MSRC) uses HF RADAR data posted on the ODU website for training exercises.

VII. Conclusions

HF RADAR surface current data in the lower Chesapeake Bay dating back to April 2007 are of good quality and provide excellent temporal and spatial coverage of observations in the region. Using these observations, basic questions about the local surface circulation can be answered which will help to improve current forecasting capabilities for the benefit of the scientific and public service communities. In particular, great potential exists to work with numerical models of the Bay region in order to validate and optimize such models with the aim of improving surface current forecasts.

Acknowledgment

We thank the owners of the sites where the HFR systems are located and our collaboration with Nancy Vorona at the Center for Innovative Technology. The AWAC data are from the City of Norfolk.